

# Neuropedagogy: Preconditions for Application of Neuroscience Results in the Education Process While Providing Feedback

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**Abstract.** As the progress in scientific areas is rapidly evolving, increasingly more and more researchers representing different areas of sciences are searching for the most suitable solution to help balance societal development and potential of personality education. New knowledge making the largest impact on the development of science, society, culture, perception and countries occurs at the intersection of different disciplines. Even though the pedagogy science is independent, it can successfully develop only in relation to other sciences because various sciences focus on its object. Rapid development of neurosciences currently meets the grounding function of many other sciences. The education science is concerned about understanding of how we learn, how we teach; whereas neuroscience seeks answering a question of how brain constructs new learning and how brain organises and processes information, how the processes taking place in brain contribute to the process of teaching and learning. Effectively provided feedback has the largest effect on learning achievement and progress. The following aspects are highly important for effective development of feedback in the education process: emotional environment and sociocultural aspects. Therefore, research studies in neurosciences carried out in this context ground the identification of the results to facilitate the development of approaches, techniques of feedback provided in the process of (self-) education.

**Keywords.** Neuropedagogy, feedback, teaching and learning.

## 1. Introduction

The present situation when the science is rapidly developing, recent research technologies are being used in practice sets high challenges for education, requires constant change and correction. Despite efforts to improve the quality of education, increasingly more and more researchers representing various areas of science search for the best solution to help balance the societal development and personality development potential in the vast flow of information. New knowledge making the largest effect on the development of science, society, culture, perception and countries occurs at the intersection of different disciplines. Even though pedagogy science is independent, it can successfully develop only through close relationship to other sciences because various sciences focus on its object. They have accumulated specific knowledge on issues which are important to the education science. The connections of pedagogy with other sciences can be characterised in several ways: some sciences are crucial

to pedagogy, others ground it, the third group support it. In these connections, the connection with psychology is very strong. It is impossible to know a subject being educated, an educator, psychological connections between them etc. without employment of psychology. Solving educational problems over the recent decade, the works by authors (Berger, Kofman, Livneh, Henik, 2007; Bradshaw, Richardson, 2009; Farkas, Grolnick, 2010; Shanks, Kim, Loke, Destin, 2010; Szente, 2007) have made a significant impact on the psychological aspect. Also, research studies acknowledge that changes in the psychological functioning are related to the changes in the brain happening throughout the entire life span of a human (Huttenlocher, Dabholkar, 1997) and that success in learning mostly depends on the performance of the brain (Durstun et al., 2001; Giedd et al., 1999; Giedd, 2004; Spreen, Risser, Edgell, 1995).

Currently proceeding rapid development of neurosciences meets the grounding function of many other sciences. A Nobel Prize laureate Kandel (2007) acknowledges that the most valuable current insights about the human mind emerged from a complex of disciplines and, according to Jensen (2008), now it is the time to integrate various disciplines of science into the process of education. The author grounding the concept of neuroeducation, Tokuhama-Espinosa (2008), analysing the integration of education sciences, psychology and neurosciences, pointed out new questions which encompass the understanding of dynamic relationships among the matters of how we learn, how we teach, how the brain constructs new learning and how brain organises and processes information, how the processes happening in the brain contribute to the process of teaching and learning, how biopsychological factors (such as stress, sleep, nutrition) contribute to efficiency of learning. It can be stated that knowledge obtained grounding on neuroscience can facilitate the development of education sciences (Carew, Magsamen, 2010; Howard-Jones, 2014). Intentionally, a new branch of science, neuropedagogy, has a scientific basis in the historical, philosophical, epistemological aspects (Chojak, 2018); and Jensen (2000), Given (2002), Wolfe (2001), Campbell (2006), Campbell et al (2007) are among the first scholars who analysed the investigation of the brain in connection to the process of learning.

Learning is a physiological process; when we are learning, changes in the brain proceed (Zull, 2011; Pery, 2000; Schulz, Sisk, 2006). In the course of the said process, elements of cognitive behaviour change being determined by alteration of hormones and neurons (Giedd, 2004). All physiological processes have effect on the formation of thinking; they contribute to the preparation of a physiological basis for processing large amount of information, management of information being applied (Sapolsky, 2017). During personality development, the nervous system serves one of the three general goals: sensory systems present information on the condition of the organism and its environment; motor systems organise and generate actions; and associative systems perform such functions as perception, attention, memory, emotions, language and thinking – all these are attributed to the area of cognition (Kandel, 2007). The latter abilities are the basis of a human, one's behaviour, history and, perhaps, understanding of the future; the investigation of them receives increasing attention (Kaku, 2014). Therefore, rapidly evolving neuroscience can help meeting the challenges raised for education in the knowledge society.

Grounding on research, the strongest impact on learning achievement and progress is made by effectively provided feedback (Khamis, Selamat, 2019; Nottingham, Nottingham, 2017; Gielen De Wever, 2015; Hattie, Gan, 2011; Hattie, 2009) which contributes when seeking higher learning outcomes. The following aspects are very important for effective development of feedback in the education process: emotional environment (how school students are encouraged, praised, rewarded, how much they experience stress, anxiety or fear); sociocultural aspects (communication, collaboration, social relationships) (Hatie, 2009). Therefore, in this

context, it is relevant to analyse the research studies on neurosciences to have the basis for identification of the results which would contribute to the development of approaches, techniques of feedback being provided during the process of (self-)education.

## **2. Research Methodology**

The present research employed the analysis of theoretical literature. It is based on this methodological principle, literature review, when existing scientific sources encompassing the analysis of investigations conducted by neuroscience are assessed in relation to the education sciences (Grant, Booth, 2009). This approach has been chosen grounding on analytical investigation (division to analytical units), conceptualisation of analytical units searching for indicators corresponding to their essence related to feedback.

Grounding on the content analysis method, information was distilled leaving the data which was significant for the analysis purposes as much as it served the organisation of feedback during lessons. Also, it provided conditions for generalisation of separate facts which were directly related to knowledge on neurosciences and their application when organising feedback during lessons. On this basis, the areas of emotional environment and sociocultural aspects were distilled: application of praising/ encouragement/ reward in the education process; effect of stress, fear and anxiety on the (self-)education process; construction of social relationships; construction of collaboration.

## **3. Results of Neurosciences and Feedback Being Provided during the Education Process.**

### *3.1. Application of Praising/ Encouragement/ Reward during the Education Process Referring to Research on Neuroscience*

Research studies found out that an attractive environment stimulates exudation of the hormone of happiness (Salimpoor et al., 2013), and this prompts learning. Therefore, the harmony between educational environment and human's positive emotions is a compulsory element in organisation of education preparing a learner to accept feedback. When organising the education process, one should regard the research results proving that constant systematic stimulation eventually reduces the sense of pleasure because the synthesis of dopamine dofamino starts receding (Schultz, 2010). In the course of formation of this mechanism, neurons produce the reducing neuromediator which takes part in the formation of a sense of habit, when rewards make effect less and less (Schultz, 2010). Therefore, one should consider unexpected, non-standard assessment which would expand the range of possible encouragement (Levy, Glimcher, 2011). The dopamine dofamino system responds to the stimuli in two ways: it activates by responding to good news and reduces after receiving bad one (Schultz, 2010). However, if a reward is expected, the level of dopamine dofamino does not change; but if encouragement is rendered quickly, unexpectedly, the system produces an increased portion of neuromediators, which, in their turn, increase the feeling of pleasure (Schultz, 2010). In such a way, during organisation of the education process, elements of unexpectedness stimulate motivation for learning by maintaining a high level of dopamine dofamino, stimulating a wish to learn. The fact that late or poor stimulation of praising reduces the exudation of dopamine dofamino (Schultz, 2010) should be regarded; therefore, the education process should employ quick, clear feedback because, in the opposite way, teacher's actions would increase demotivation in students.

Thus, neurones of dopamine dofamino react to reward only as much as it differs from the predicted one (Schultz, 2010). The expectancy of reward renders a higher pleasure than that of reward itself (Knutson, Adams, Fong, Hommer, 2001). One's purposeful behaviour being stimulated on target to get the reward forms a sense of pleasure (Numan, Stolzenberg, 2009).

In such a way, an understanding of emerging motivation is being formed. If a quick reward is chosen, receptors of dopamine dofamino operate in the limbic system; and when a postponed reward is chosen, areas of frontal cortex, source of will, are activated (Sapolsky, 2017). In the ontogenesis of different people, different connections among the dopamine dofamino system, prefrontal cortex and limbic system form; therefore, it can be considered that a size of reward, its speed and a probability of getting it are different. In other words, people make decisions to get a reward or postpone it in different ways (Pine, Shiner, Seymour, Dolan, 2010), and only a human can indefinitely postpone the reward (Sapolsky, 2017). This forms an understanding about the manifestation of will, long-term plans to achieve the goal. Therefore, teacher's task is to create conditions for students to plan their learning having clear outcomes in mind because this is the best stimulus and motivation to perform.

To sum up, it can be stated that:

- in the course of the formation of the synthesis of dopamine dofamino, neurones produce a reducing neuromediator which is involved in the formation of a sense of habit. This means that, for instance, praising, rewards make effect less and less. Therefore, when providing feedback, it is suggested to refuse constant systematic stimulation, praising, rewarding, which would eventually diminish the sense of pleasure. It is suggested to focus on non-standard feedback, unexpected questions during the education process.
- if a reward is expected, the level of dopamine dofamino does not change; but if encouragement, praising are expressed quickly, unexpectedly, the system creates an increased portion of neuromediators, which, in their turn, increase a sense of pleasure. Therefore, unexpected, non-standard feedback will stimulate motivation for learning by maintaining a high level of dopamine dofamino, stimulating a wish to learn. The waiting for reward renders a higher pleasure than the reward itself;
- late or poor stimulation or praising decreases the exudation of dopamine dofamino; therefore, it is suggested to render quick, clear feedback in the education process because, in the opposite way, teacher's actions would increase demotivation in students;
- the purposeful behaviour being stimulated on target to get the reward forms a sense of pleasure which in the ontogenesis of different people forms different connections among the dopamine dofamino system, prefrontal cortex and limbic system. Therefore, when providing feedback, it is suggested to assess that a size of a reward, its speed and a probability of getting it are different for each student, i.e. students make decisions to get a reward or postpone it in different ways. This forms an understanding about the manifestation of will, long-term plans to achieve the goal;
- neurones of dopamine dofamino react to a reward as much as it differs from the predicted one. Therefore, when providing feedback, teacher's task is to create conditions for students to plan their learning having clear outcomes in mind because this is the best stimulus and motivation to perform;
- when providing feedback, it is suggested to avoid external rewards because, having received it for achievement, a sense of personal responsibility for own learning is withdrawn (i.e. learners who receive only external rewards learn less, since pursuit of rewards and not the process of learning becomes their major goal). It is advised to deliver external reward through feedback only to raise learner's interest in a subject being taught.

### *3.2. Effect of Stress, Fear and Anxiety on the (Self-)Education Process Referring to Neuroscience Research*

Our life is full of moments when we make important and complex decisions; during these moments, we are affected by strong stress and high tension. Stress disturbs the proceeding of organism's, other organs' reactions; it also disturbs performance of the brain; short-term memory and concentration of attention become poorer (Joffe et al., 2019; Seaward, 2019). During intensive stress, performance of prefrontal cortex, which activates the effect of the amygdala on emotions being formed, weakens (Young, Sahakian, Robbins, Cowen, 1999). Stress can negatively affect effective processing of information, no longer link it to earlier experiences (Kausche, Schwabe, 2020), modifies learning and memory, which cause alterations in the strategies of learning, learning difficulties occur (Diamond, Campbell, Park, Halonen, Zoladz, 2007) because a number of strategies for the decision-making diminishes, responses to new knowledge and formation of skills become poorer (Kausche, Schwabe, 2020). Prefrontal cortex reduces the control of the amygdala, which results in increased emotional sensitivity, worsened quality of the working memory (Schwabe, Wolf, 2012).

According to scientists Erişti, Akdeniz (2016), learning is enhanced by challenges and weakened by threat. Performance of the brain becomes poorer if fear or anxiety occurs. On the contrary, the will to learn increases to reach a high level when the brain is forced to properly (motivating to put endeavours) perform. A sense of despair is a major reason for reduction of motivation. In such a case, the area of perception narrows down and primitive behaviour automatically manifests. Authors argue that that hippocampus, which is a part of the limbic system, is the most stress-sensitive part of the brain. Some channels which reach specific parts of the brain perform less than expected due to over-sensitivity of hippocampus in a case of fear. Such situations as fear, anxiety and stress obstruct interaction among parts of the brain at the predicted level. When senses of fear, anxiety and stress are strong, hippocampus tends to collaborate with other parts of the brain more seldom; therefore, this situation negatively affects the quality of learning.

To sum up, it can be stated that:

- during intensive stress, performance of prefrontal cortex, which activates the effect of the amygdala on emotions being formed, weakens. This means that it negatively affects the effective processing of information, responses to new knowledge and formation of skills worsen. Therefore, when providing feedback, it is suggested to choose the ways and approaches which would not cause stress to a school student; to provide conditions for the development of relationships based on trust, support and understanding;
- hippocampus, which is a part of the limbic system, is the most stress-sensitive part of the brain. Some channels which reach specific parts of the brain perform less than expected due to over-sensitivity of hippocampus in a case of fear. When senses of fear, anxiety and stress are strong, hippocampus tends to collaborate with other parts of the brain more seldom; therefore, this situation negatively affects the quality of learning. When providing feedback, it is worth emphasising that the learning is enhanced by challenges and weakened by threat. Therefore, it is suggested to eliminate a sense of despair which reduces flexibility, narrows the area of understanding down, provides conditions for manifestation of primitive behaviour in the education process;
- while learning, changes in the brain proceed and these changes are largest when emotions become part of the learning. Therefore, when providing feedback, it is important to meet the following aspects: to create conditions for one's target-oriented actions because, in such a way, a learner experiences joy; it is good to create a situation of learning which would be pleasant for a learner; however, it is much more important to create such culture of feedback which would engage in the process of investigation, allow gaining meaningful experience. In such a way, learners perceive that they progress



(their knowledge expands/ moves forward), and the brain rewards us with a sense of pleasure for that.

### *3.3. Construction of Social Relationships during the Education Process Grounding on Neuroscience Research*

The dopamine-dopaminergic system of the brain, also called the system of pleasure, joy and incentive, is dedicated to exude dopamine-dopaminergic of the neuromediator. It produces dopamine-dopaminergic as a response, and, when a stimulus disappears, synthesis of dopamine-dopaminergic recedes (Danjo, Yoshimi, Funabiki, Yawata, Nakanishi, 2014). During the research it was found out that synthesis of dopamine-dopaminergic activates in the course of social cooperation, while performing collective tasks (Sanfey, Rilling, Aronson, Nystrom, Cohen, 2003), when imposing punishment (De Quervain, Fischbacher, Treyer, Schellhammer, 2004) and also when reacting to an aesthetical pleasure (Salimpoor et al., 2013).

Hormones, like neuromediators, take part in regulation of human feelings and behaviour. It is worth noting that testosterone is produced in organisms of both sexes, only in different amounts of concentration, depending on season and maturity of one's organism. The amygdala, like other parts of the brain, has a high amount of testosterone receptors; therefore, this hormone can make effect on performance of parts of the brain. Testosterone is capable of reducing a mirror effect of hormones (Hermans, Erno Jan, Putman, Van Honk, 2006); it also enhances self-confidence and causes the sense of optimism, reduces the sense of fear and anxiety (Tsai, Sapolsky, 1996). In some cases, testosterone increases an over-estimated self-confidence; therefore, people can become ill-natured, egoistic (Wright et al., 2012), sometimes it increases impulsiveness or makes taking silly risks (Bos, Hermans, Ramsey, Van Honk, 2012). Research studies found out that an effect of the same hormone in different situations varies much and this context occurs at the neurobiology level, when the amygdala and hippocampus interact with testosterone (Hermans, Ramsey, van Honk, 2008). A result of such interaction demonstrates that the amygdala, responding to social environment, is supported by testosterone which increases the intensity of amygdala's reaction.

Not only hormones influence cognitive processes. It was found out that the area of prefrontal cortex increases when amount of social contacts rises (Lewis, Rezaie, Brown, Roberts, & Dunbar, 2011); and injuries of this cortex determine exchanges of social behaviour (Glenn, Johnson, Raine, 2013).

To sum up, it can be stated that:

- the amygdala, responding to social environment, is supported by testosterone which increases the intensity of amygdala's reaction. This means, that social, cultural environment, social cooperation are highly important in the education process. Therefore, when providing feedback, it is suggested to create such educational environments which would create conditions for expansion and maintenance of as close relationships with school students as possible.

### *3.4. Construction of Collaboration in the (Self-)Education Process Grounding on Neuroscience Research*

A human has two important hormones called neuropeptides (vasopressin and oxytocin) which, after penetrating blood, start their independent performance (Bear, Connors, Paradiso, 2007). Research studies found out that these hormones make impact on performance of the brain parts belonging to the dopamine-dopaminergic system. For example, oxytocin and vasopressin stimulate strength of relationships (Westberg, 2015) between women and men (Schneiderman, Zagoory-Sharon, Leckman, Feldman, 2012; Walum et al., 2008), parents and children (Feldman,

Gordon, Influx, Gutbir, Ebstein, 2013; King, Walum, Inoue, Eyrich, Young, 2016). During the formation of attachment, oxytocin reduces performance of the amygdala, manifestations of aggression and anxiety decrease, the parasympathetic nervous system activates, the sense of security rises (King et al., 2016). Oxytocin increases social enhancement when an effect of prosocial behaviour encouraged by activities of other people is felt (Kogan et al., 2011). Researchers (De Dreu, Greer, Van Kleef, Shalvi, Handgraaf, 2011) found out that oxytocin forms purposeful humbleness for a particular group only. In other words, people more willingly help “their own” identified group or person; therefore, ethnocentrism and xenophobia are a negative side of the neuropeptide. Investigating the brain responses to mutual collaboration after eliminating factors having a negative effect on the brain, Caine (2002) observed that a created atmosphere of co-creation bringing courage and self-confidence makes effect on the quality of learning.

To sum up, it can be stated that:

- hormones neuropeptides stimulate the strength of relationships (between parents and children, teacher and students etc.). During the formation of attachment, oxytocin reduces performance of the amygdala; therefore, manifestations of aggression and anxiety decrease, the parasympathetic nervous system activates, the sense of security rises. When providing feedback, it is important to create conditions to feel secure (it will determine the acceptance of feedback); to form as strong communal relationships in the education process as possible to make cultural identity enhance the effect of neuropeptides;
- after eliminating factors having a negative effect on the brain, the created atmosphere of co-creation bringing courage and self-confidence makes effect on the quality of learning;
- social support which is important to maintain performance of neuropeptides will provide conditions for effectiveness of feedback when solving complex tasks. Sincere teacher’s engagement in performance carried out by a student will form a mutual socially positively directed connection and increase general agreement with strategies for completion of tasks, students’ motivation for learning will increase and satisfaction of teachers with results of work performance will rise as well.

#### **4. Conclusions**

The largest effect on learning achievement and progress is made by effectively provided feedback which contributes when seeking higher learning outcomes. The following aspects are important to effective development of feedback in the education process: emotional environment (how school students are being encouraged, praised, rewarded, how much they experience stress, anxiety or fear); sociocultural aspects (communication, collaboration, social relationships).

Grounding on neuroscience research, emotional environment in the education process will improve when praising/ encouragement/ rewarding are purposefully employed. It is suggested to refuse constant systematic stimulation, praising, rewarding, which would eventually diminish the sense of pleasure, and to focus on quick, clear, non-standard feedback, unexpected questions because they will stimulate motivation for learning, a wish to learn. When providing feedback, it is suggested to assess that a size of reward, its speed and a probability of getting it are different for each student, i.e. students make decisions to get a reward or postpone it in different ways. This forms an understanding of manifestation of will, long-term plans to achieve a desired goal. When providing feedback, it is advised to avoid external rewards because having received it for

achievement, a sense of personal responsibility for own learning is withdrawn (i.e. learners who receive only external rewards learn less, since pursuit of rewards and not the process of learning becomes their major goal).

To ensure emotional environment during provision of feedback, it is important to select the ways and approaches which would not cause stress, anxiety and fear to school students because this disturbs student's cognitive performance, complicates the decision-making, distorts expression of emotions. All these complicate communication and collaboration, personal self-assessment and self-control decrease. All consequences complicate provision and reception of feedback between student and teacher, disturb formation of interactions which are required for the education process.

Grounding on neuroscience research, sociocultural strategies will have meaning in the education process when social relationships and collaboration (to develop social, cultural environment, approaches, social cooperation, as strong communal relationships as possible; to create conditions to feel secure (it will determine the acceptance of feedback)) are purposively constructed.

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